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Antenna Design for Spin Wave Caustic Beams

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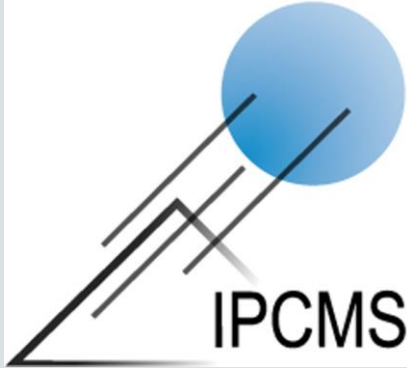
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Fundings



Thomas Jefferson
Magnon
Interferometry



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Motivations

- ▶ **Non-reciprocal magnonic devices**
Miniaturizing isolator, circulator, delay lines
- ▶ **Shaping spin-wave beams in extended layer**
Development of magnon interferometric devices [1-3]
- ▶ **Diffraction model for in-plane spin-wave modes**
Efficient tool to map the Near-Field Diffraction (NFD) patterns of any shape of spin-wave antennas [4]

Near-Field diffraction model for in-plane magnetized films

❖ Kalinikos's approach to express $\vec{m}(u, v, t)$ [5]

- **(ξ, η, ζ) SW Propagation frame** \Rightarrow dynamic dipolar field $\vec{h}_d(\xi)$ from Green functions [6]

$$\vec{h}_d(\xi) = \int_{-\frac{l}{2}}^{\frac{l}{2}} \vec{G}_{xy}(\xi - \xi') \vec{m}(\xi') d\xi' = -\vec{N}_{dip} \vec{m}$$

$$\vec{G}_{\xi\eta\zeta}(\xi - \xi') = \begin{pmatrix} G_p - \delta(\xi - \xi') & 0 & iG_Q \\ 0 & 0 & 0 \\ iG_Q & 0 & -G_p \end{pmatrix} \Rightarrow \vec{N}_{dip}^{00} = \begin{pmatrix} 1-P & 0 \\ 0 & P \sin^2 \phi \end{pmatrix}$$

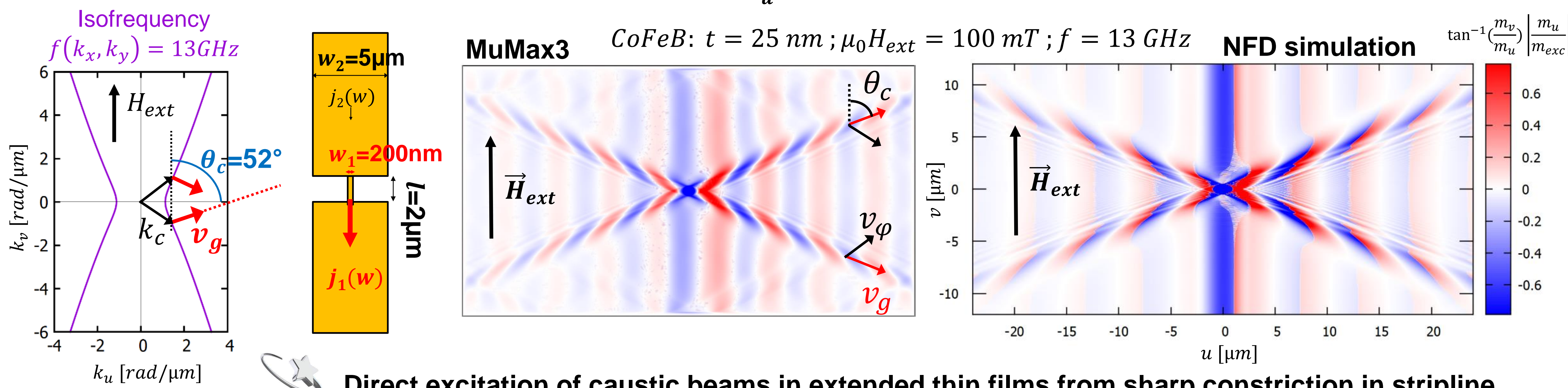
change of frame $(\xi, \eta, \zeta) \Rightarrow (x, y, z)$ $(P = 1 - \frac{1-e^{-kt}}{kt})$

- **(x, y, z) $\vec{M}(\vec{r}, t)$ frame** \Rightarrow Linearizing LLG

$$i\omega \vec{m} = -\gamma \mu_0 H_{equ} \vec{m} \times \vec{u}_z + \gamma \mu_0 M_{equ} \vec{h} \times \vec{u}_z - \alpha i\omega \vec{m} \times \vec{u}_z \Rightarrow \vec{\chi}^{-1} \vec{m} = \vec{h}_{exc} \Rightarrow \frac{1}{\omega_M} \begin{pmatrix} \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,xx}^{00} & -i\omega + \omega_M \vec{N}_{d,xy}^{00} \\ i\omega + \omega_M \vec{N}_{d,yx}^{00} & \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,yy}^{00} \end{pmatrix} \begin{pmatrix} m_x \\ m_y \end{pmatrix} = \begin{pmatrix} h_x \\ h_y \end{pmatrix}$$

- **(u, v, ξ) Lab frame** - antenna orientation $\Rightarrow FFT^{-1}\{\vec{m}(\vec{k})\} \Rightarrow \vec{m}(u, v, t) = e^{i\omega t} \iint_{-\infty}^{+\infty} dk_u dk_v \vec{\chi}(k_u, k_v) \cdot \vec{h}_{exc}(k_u, k_v) e^{-i(k_u u + k_v v)}$

❖ Anisotropic dispersion \Rightarrow Caustic beam when $\frac{d^2 k_v}{dk_u^2} = 0$

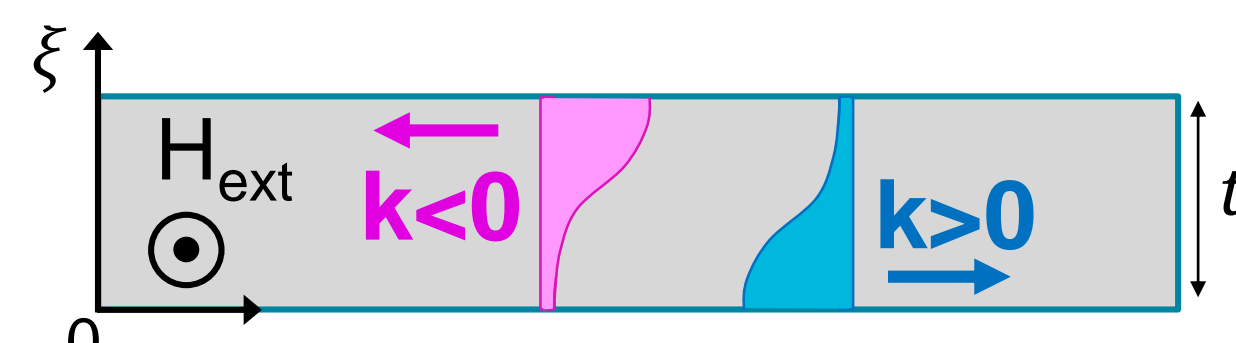
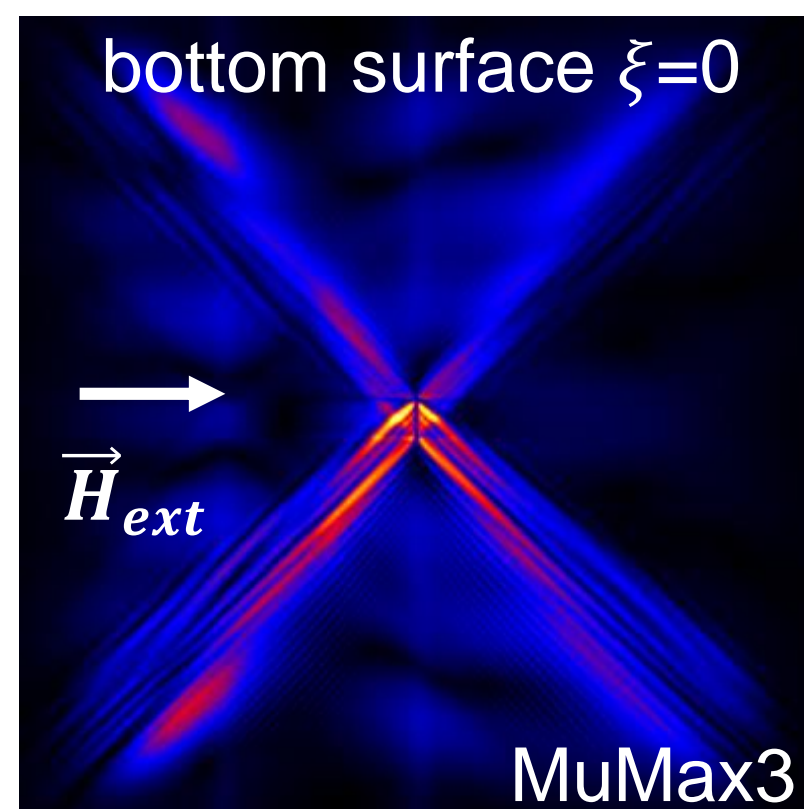


Caustic beam definition

❖ Thickness dependence $t_{YIG} = 200 \text{ nm}$

$$w_1 = 200 \text{ nm} \\ w_2 = 10 \mu\text{m}; l = 2 \mu\text{m}$$

$$\mu_0 H_{ext} = 50 \text{ mT}; f = 3.2 \text{ GHz}$$



non-uniform thickness profile
 \Rightarrow need to account for higher order mode ($n > 0$), and their coupling:

$$\begin{pmatrix} \vec{\chi}_{00} & \vec{\chi}_{01} & \vec{\chi}_{02} & \dots \\ \vec{\chi}_{10} & \vec{\chi}_{11} & \vec{\chi}_{12} & \dots \\ \vec{\chi}_{20} & \vec{\chi}_{21} & \vec{\chi}_{22} & \dots \\ \dots & \dots & \dots & \dots \end{pmatrix} \begin{pmatrix} \vec{h}_0 \\ \vec{h}_1 \\ \vec{h}_2 \\ \dots \end{pmatrix} = \begin{pmatrix} \vec{m}_0 \\ \vec{m}_1 \\ \vec{m}_2 \\ \dots \end{pmatrix}$$

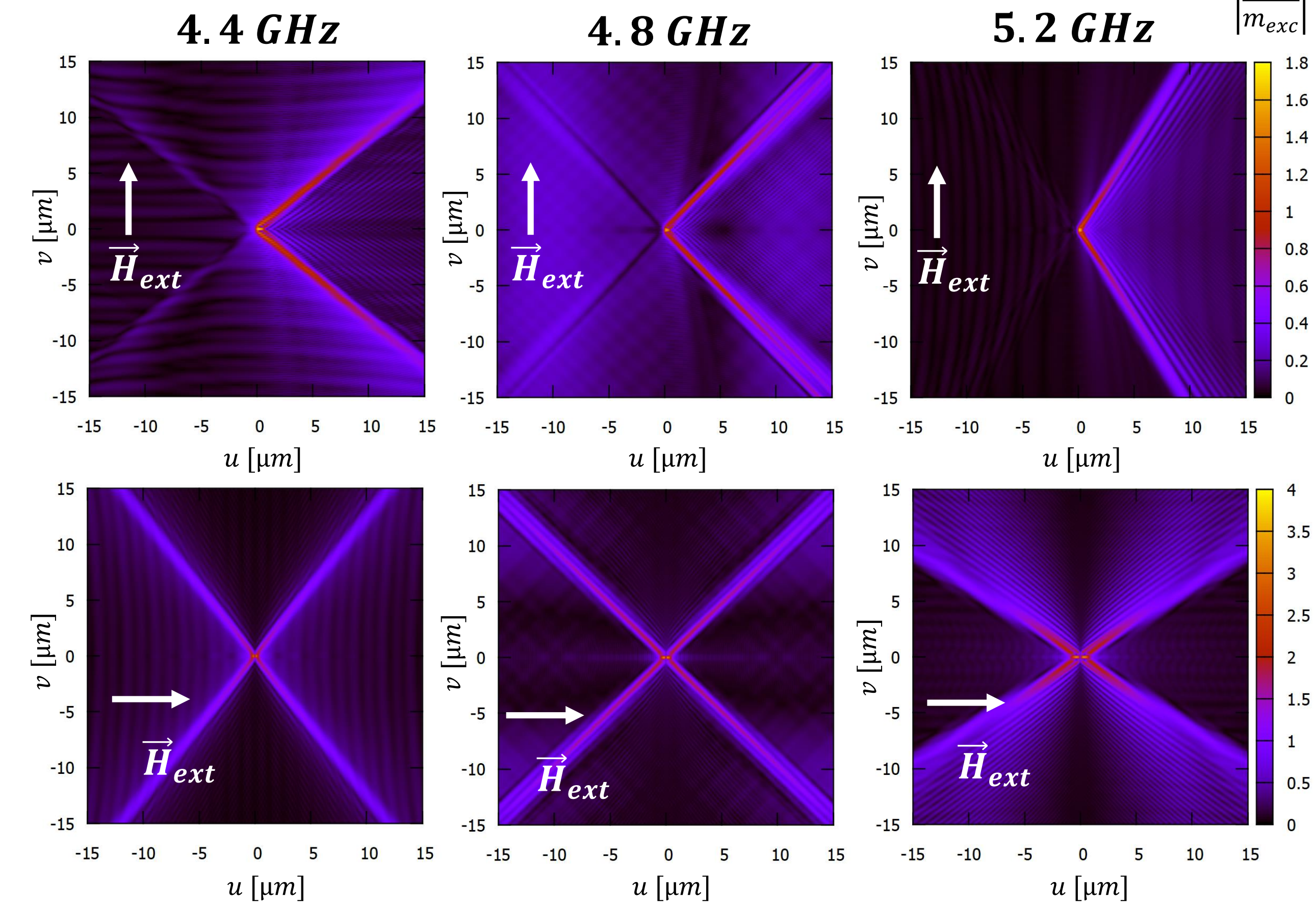
Conclusions

- ▶ Validation of NFD model for in-plane mode for thin film \Rightarrow Caustic beam excitation from point-like excitation
- ▶ Powerful tool to explore constriction shapes for spin-wave beamforming
- ▶ Upgraded needed for NFD model to obtain non-reciprocal thickness profile of the diffraction patterns

❖ Frequency and constriction size dependence

$$w_1 = 200 \text{ nm}; w_2 = 40 \mu\text{m}; l = 500 \text{ nm}$$

$$\mu_0 H_{ext} = 100 \text{ mT}; t_{YIG} = 200 \text{ nm}$$



Caustic beam angle adjustable with frequency